CALIPSO Quality Statements: Lidar 532-nm Detectors Transient Response

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Data Quality Statement relating to the **Lidar 532-nm Detectors Transient Response** (Version 1.10, December 8, 2006).

Introduction

This document provides a high-level quality assessment of the lidar 532 nm detector response. As such, it represents the minimum information needed by scientists and researchers for appropriate and successful use of the lidar Level 1 and 2 data products. We strongly suggest that all authors, researchers, and reviewers of research papers review this document for the latest status before publishing any scientific papers using lidar data products.

The purpose of these data quality summaries is to inform users of the accuracy of CALIOP data products as determined by the CALIPSO Science Team and Lidar Science Working Group (LSWG). This document is intended to briefly summarize key validation results; provide cautions in those areas where users might easily misinterpret the data; supply links to further information about the data products and the algorithms used to generate them; and offer information about planned algorithm revisions and data improvements.

Additional Documentation and References

- PC-SCI-503 : CALIPSO Data Products Catalog (PDF)
- Data analysis overview: Fully automated analysis of space-based lidar data: an overview of the CALIPSO retrieval algorithms and data products (PDF)

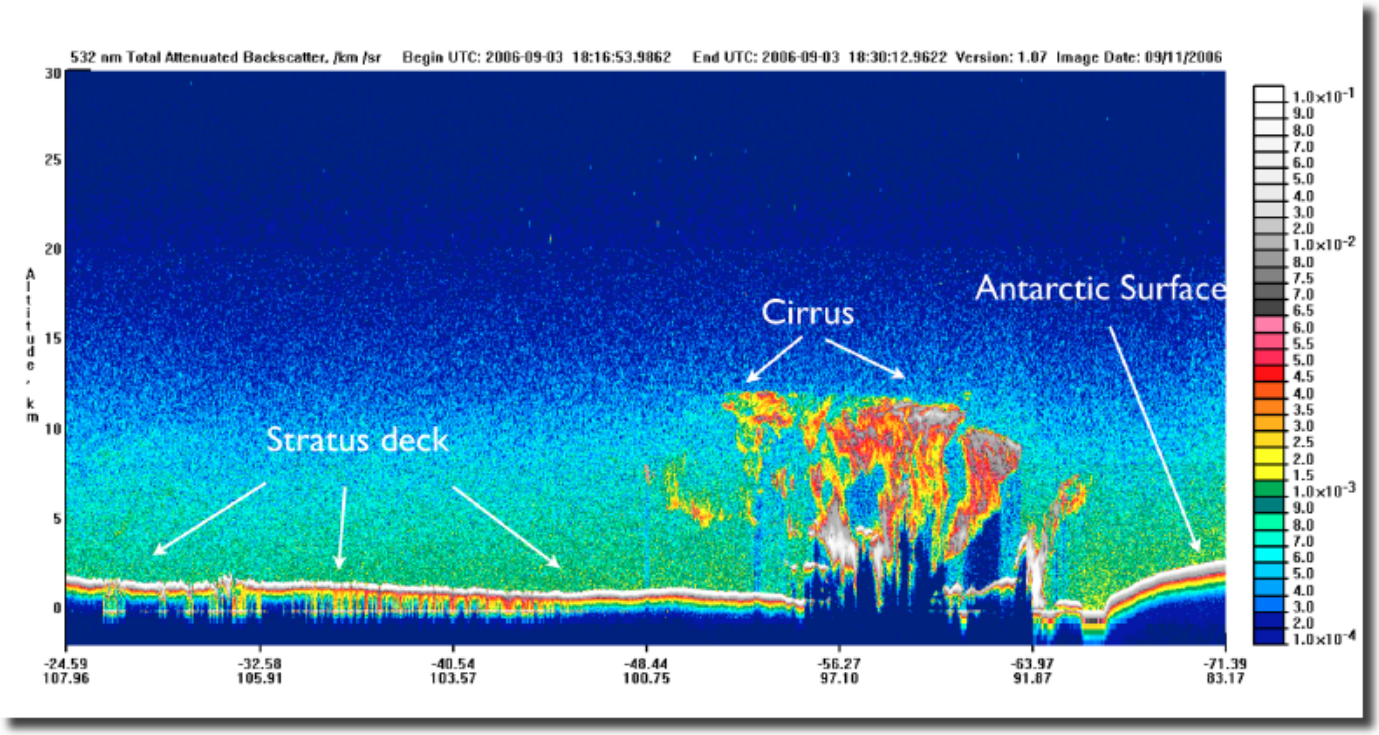
Page Topics

532 nm detector non-ideal transient recovery

The 532 nm detectors (parallel and perpendicular) photo multiplier tubes (PMTs) both exhibit a non-ideal recovery of the lidar signal after a 'strong' backscattering target has been observed. Examples of strong targets are water clouds and surface returns.

PMT afterpulsing (ionization of residual gas) is the likely cause of the non-ideal transient recovery. This effect is well documented in the literature for photon counting applications. The time scale of the effect is dependent on PMT voltage, gas species, and PMT internal geometry. It is also possible that the non-ideal transient recovery is what is commonly called signal induced noise. It is unlikely that the lidar receiver electronics are the source of the problem because the 1064nm channel uses a similar design and is performing well.

Example of the non-ideal transient recovery in browse images



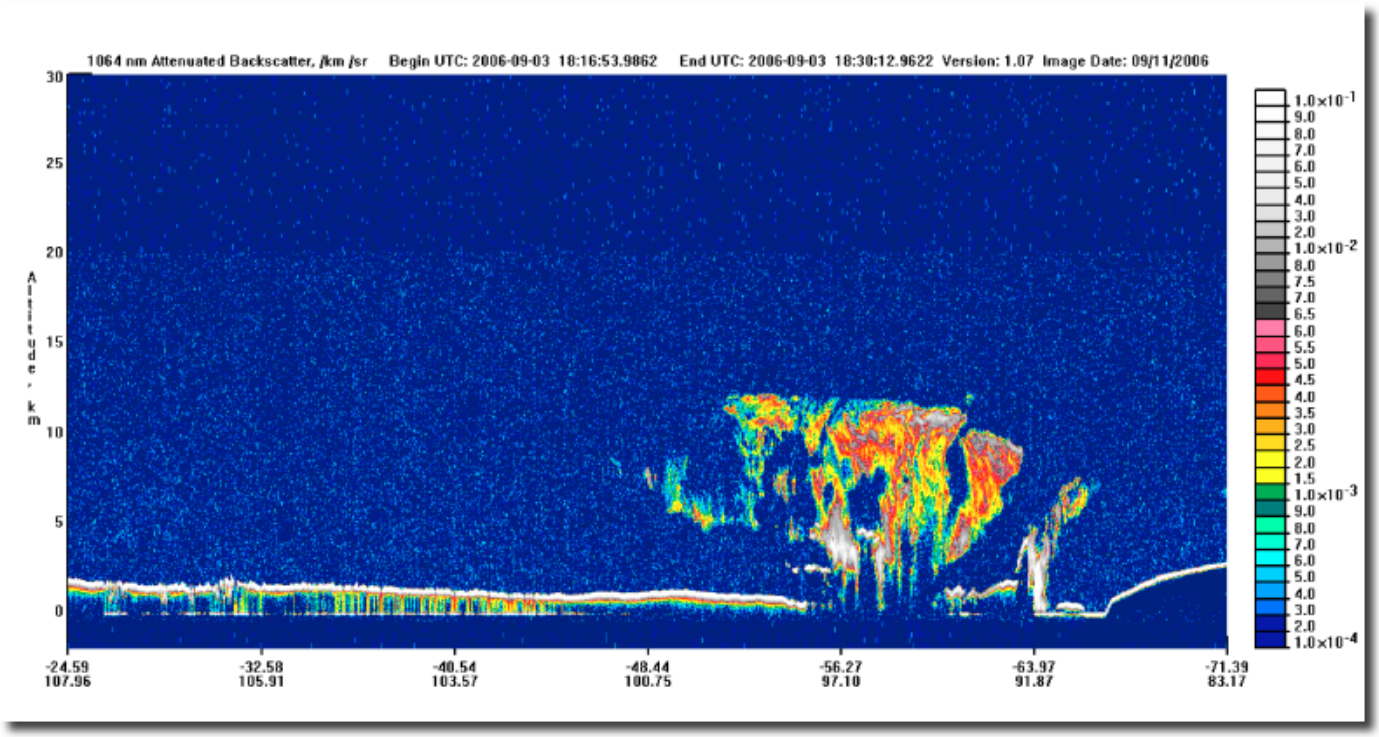


Figure 1: Browse images of 532 nm (top) and 1064 nm (bottom) total attenuated backscatter. The 532 nm non-ideal transient recovery is seen in the 532 nm image as a gradual transition of colors from high attenuated backscatter values to lower ones for strong backscatter targets (i.e. stratus deck on the left, and the Antarctic surface return on the right. Compare these features to the 1064 nm image, where the detector response is normal, and these features appear as an almost solid band of white.

Note that the cirrus cloud structure (center right) looks about the same in both the 532 nm and 1064 nm images. This is because there is little to no contribution from the transient response artifact in these weak scattering features.

Examples of the transient response in profile data

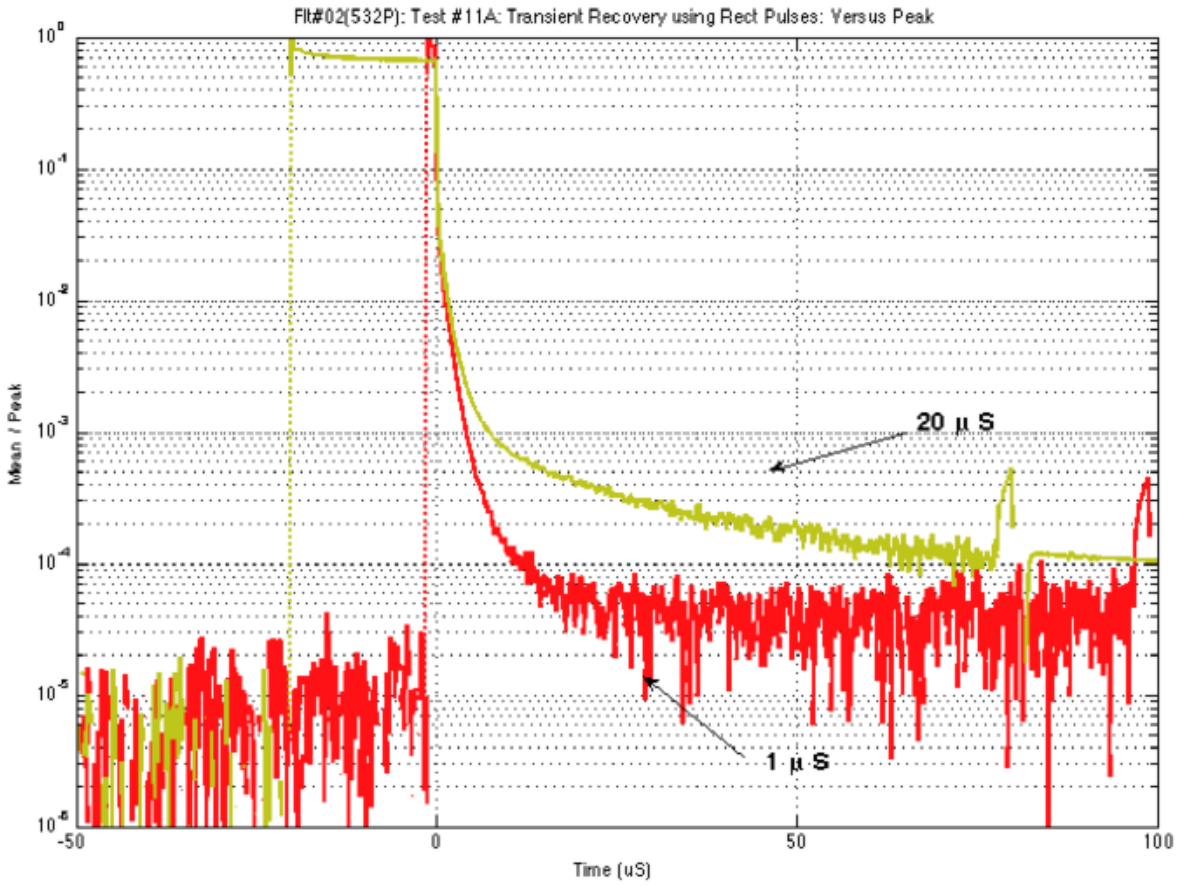


Figure 2: This shows the detector response from laboratory measurements. The input was a light pulse of constant amplitude for 1 µs (red), and 20 µs (brown). The amplitude corresponds roughly to what would be measured with the CALIOP instrument on-orbit from an optically dense water cloud. Note that the duration and amplitude similar to the 20 µs pulse would never be measured on-orbit from a real atmospheric features due to signal attenuation through the feature. For ideal detector response the signal should return to the baseline value (~$3x10^{-5}$) at time = 0.

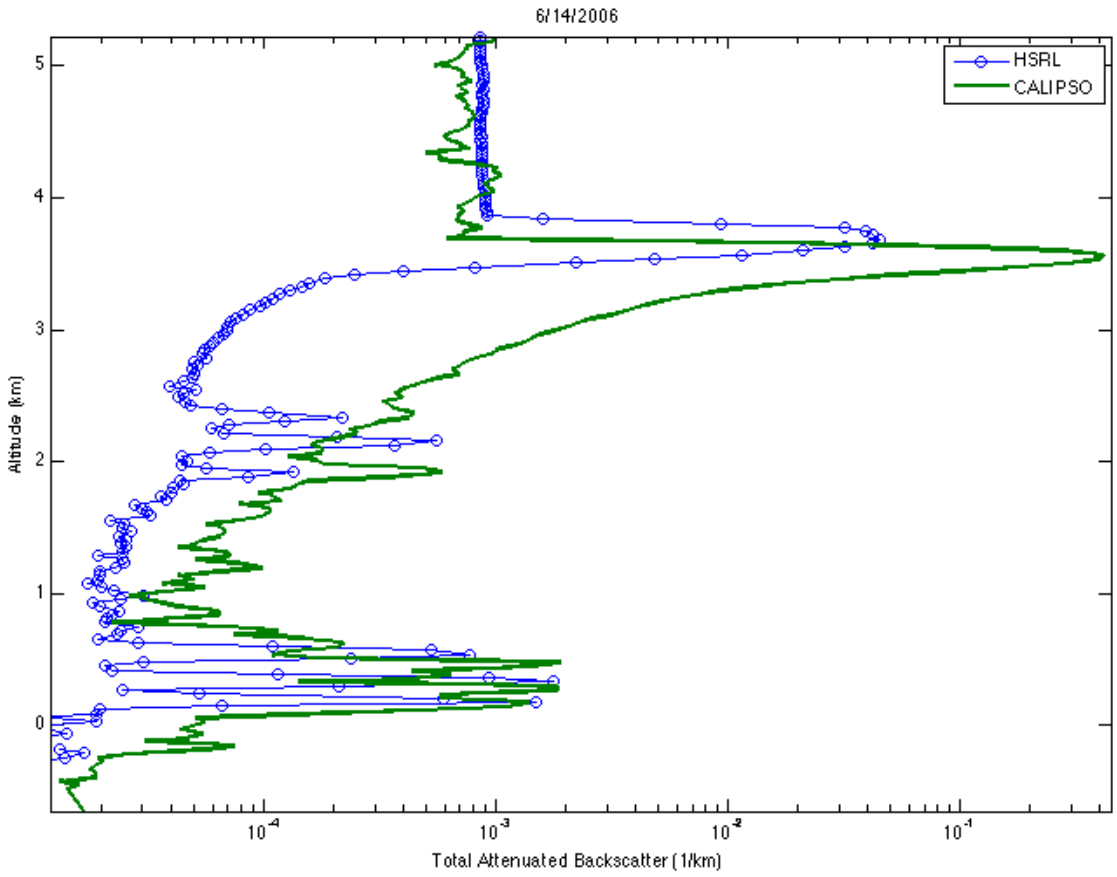
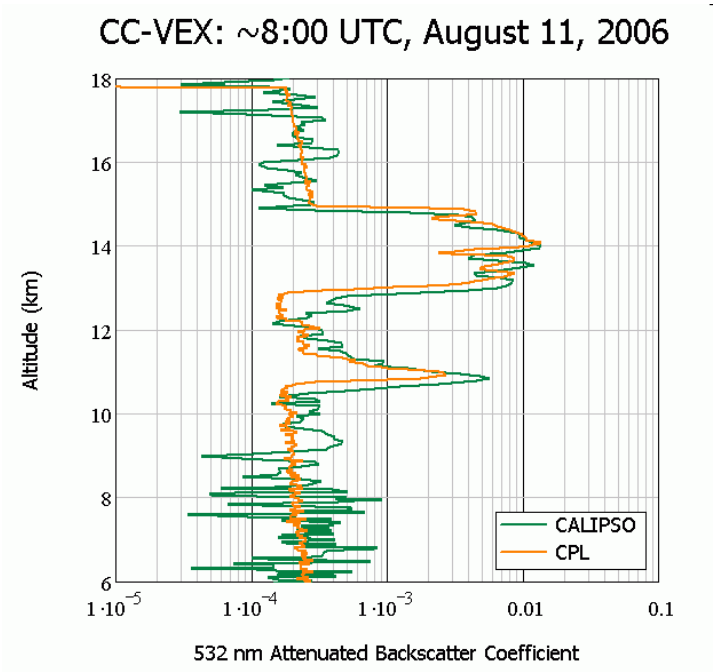
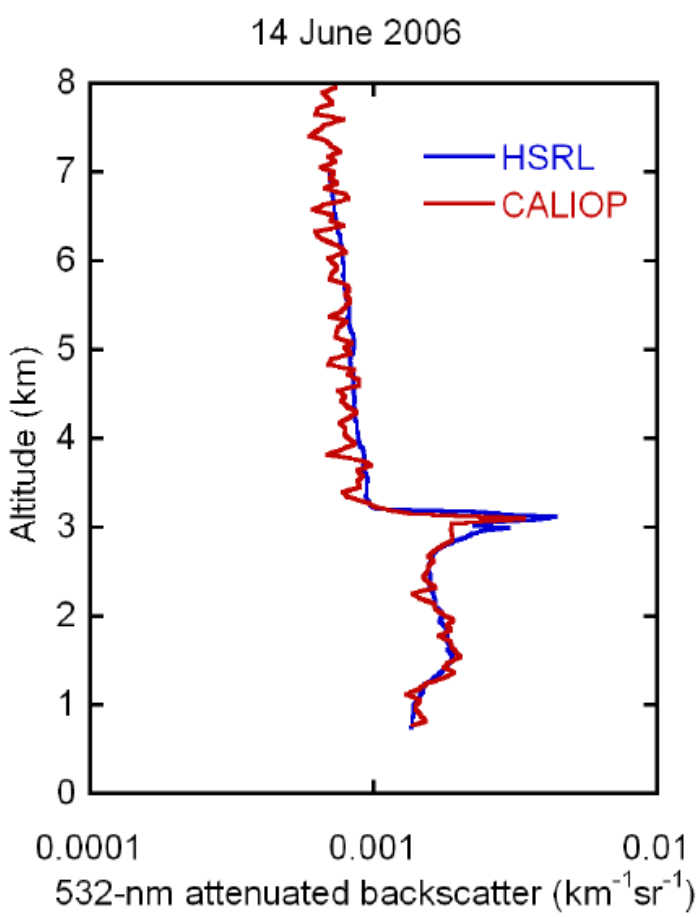


Figure 3: A comparison of the Langely Airborne HSRL and CALIPSO coincident measurements of a water cloud from 6/14/2006. Time from the coincidence is approximately 30 minutes. The recovery artifact is the decaying portion of lidar signal that extends from ~3100 m to ~1000m. When comparing these data, keep in mind that the water cloud top has changed between the observation times. Also, the CALIPSO and HSRL viewing geometries are considerably different, and there is a contribution from multiple scattering in the CALIPSO observation.





Figures 4a and 4b: Comparisons of CALIPSO and CPL for a cirrus cloud measurement (left) and with the Langely Airborne HSRL for an aerosol layer (right). Both these comparisons demonstrate that the non-ideal transient recovery from weaker scattering layers is negligible. For the CPL-CALIPSO observations the small differences can be attributed to spatial and temporal mismatching and differences in the viewing geometry of the two instruments. Multiple scattering contributes to some of the differences observed between the CALIPSO and CPL measurements.

Analysis and correction techniques

Lab data was collected on flight hardware in 2002 to characterize the 532 nm parallel and perpendicular channel detectors response. The data set consists of 87 different tests using square wave 'clouds' of varying amplitude and duration. The surface return can also be used to characterize the non-ideal recovery if the peak signal is not saturating the low-gain digitizer, and the is sufficient time between the surface and the last range bin.

Analysis has started on this data set to characterize the non-ideal transient recovery. So far, the analysis has demonstrated that the non-ideal recovery behaves like an afterpulse signal. The observed response is a function of both the signal amplitude and duration.

A Richardson-Lucy deconvolution algorithm has been applied to the lab data to retrieve the instrument response function. This was done by assuming that the true signal was a square wave with the duration as the detector illumination source. The retrieved response functions from the 532 nm parallel channel detector for various lighting conditions (different pulse amplitudes and widths) are shown in figure 5.

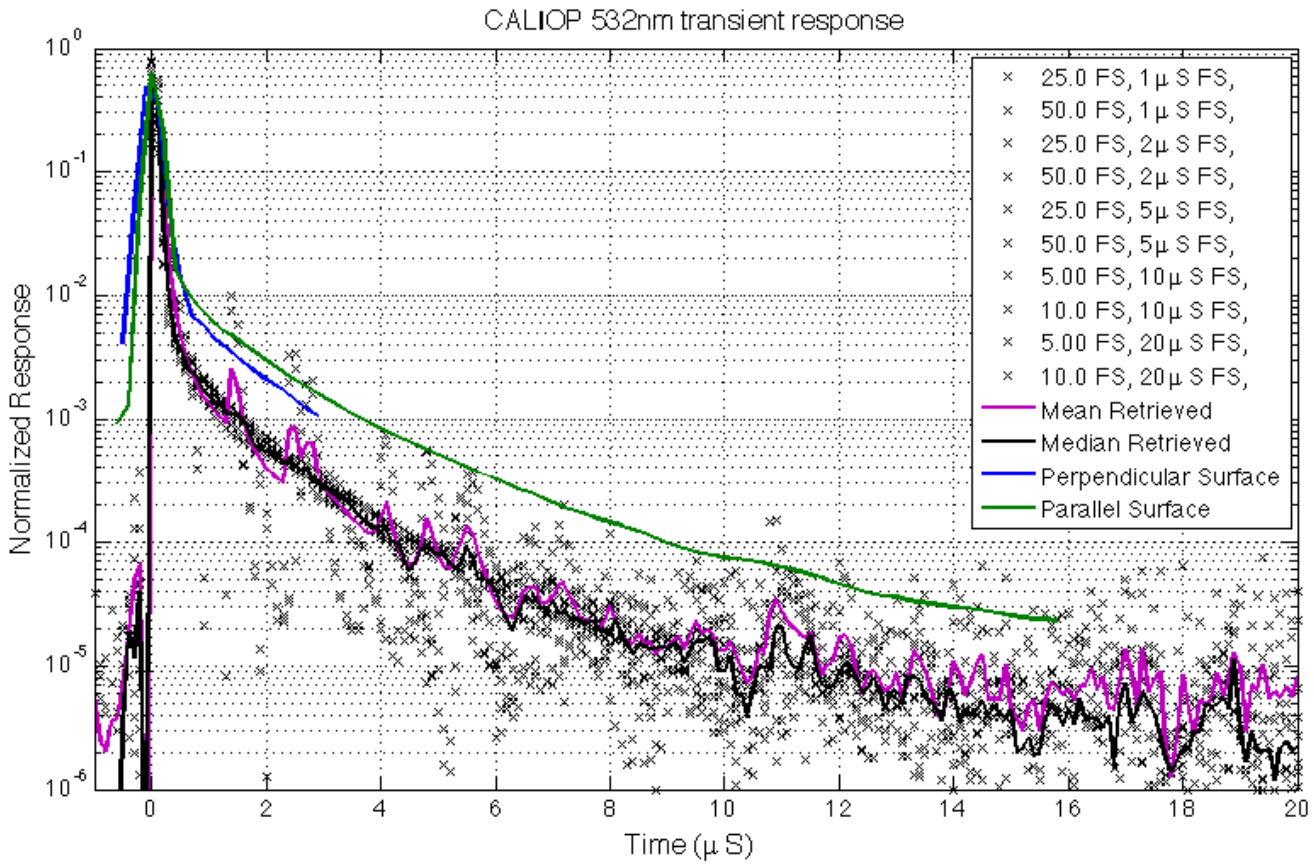


Figure 5: Retrieved response function from lab data compared to the surface return response function measured from a lake at altitude of ~4 km.

The retrieved response function or a suitable surface return can be used to remove the non-ideal transient recovery from the lidar Level 1 data using a Richardson-Lucy type deconvolution algorithm. Care needs to be taken in the application of such an algorithm because of the non-uniform range binning of the profile data.

Summary

Further characterization of the non-ideal transient recovery is underway and techniques are being investigated to remove this artifact from the 532 nm lidar data.

In the meantime, users of Lidar Level 1B profile data should use extreme caution when doing investigations of strong backscattering targets, like optically dense water clouds. Since the non-ideal response of the 532 nm parallel and perpendicular channels are slightly different, some artifacts in the calculated depolarization ratio may be observed below strong backscattering targets.

There is no geophysically meaningful information in the subsurface signal return. Subsurface can be assumed to be 1 or 2 bins beyond the maximum value obtained in the surface spike.

Users of Lidar Level 2 layer products can expect that the bases of strong scattering targets (i.e. optically dense water clouds) will be lower than expected. In most of these cases however, the observed layer is opaque to the lidar and the measurement of the true cloud base is not possible.